WORKING PAPER SERIES

Identifying the Liquidity Effect: the Case of Nonborrowed Reserves

Daniel L. Thornton

Working Paper 1996-002A
http://reseach.stlouisfed.org/wp/1996/96-002.pdf

FEDERAL RESERVE BANK OF ST. LOUIS
Research Division
411 Locust Street
St. Louis, MO 63102

IDENTIFYING THE LIQUIDITY EFFECT: THE CASE OF NONBORROWED RESERVES

February 1996

ABSTRACT

Despite the fact that efforts to identify it empirically have largely been futile, the liquidity effect plays a central role in conventional monetary theory and policy. Recently, however, an increasing volume of empirical work [Christiano and Eichenbaum (1992a,b), Christiano,, Eichenbaum and Evans (1994a,b) and Strongin (1995)] has supported the existence of a statistically significant and economically important liquidity effect when nonborrowed reserves is used as the indicator of monetary policy. This paper shows that there is an identification problem associated with using nonborrowed reserves. Specifically, the strong negative relationship between nonborrowed reserves and the funds rate can stem from the presence or absence of a liquidity effect. The paper points out how changes in the demand for borrowed reserves can be used to identify whether the relationship between nonborrowed reserves and the funds rate is due to liquidity effect. The evidence presented suggests that the "liquidity effect" that Christiano, Eichenbaum and Evans and others have identified is actually due to the interest sensitivity of the demand for borrowed reserves and the definition linking nonborrowed and borrowed reserves. Consequently, the evidence suggests that the liquidity effect is nil.

JEL CLASSIFICATION: E40, E52

Daniel L. Thornton
Assistant Vice President
Federal Reserve Bank of St. Louis
411 Locust
St. Louis, MO 63102

I would like to thank Adrian Pagan and John Robertson for providing me with their computer programs and data. This paper was begun when the author was a visiting scholar at The Business School, City University, LONDON.

The liquidity effect—the transient yet persistent declines in real and nominal short-term interest rates associated with unanticipated expansionary monetary policy shocks—plays a central role in conventional monetary theory and policy.[1] Despite its prominent role, the liquidity effect has received scant empirical support [Cagan and Gandolfi (1969), Melvin (1983), Thornton (1988b), Reichenstein (1987) and Leeper and Gordon (1992)]. A number of analysts [Bernanke and Blinder (1992), Christiano and Eichenbaum (1991, 1992a,b) and Goodfriend (1991)] have argued, however, that the lack of empirical support is a manifestation of the Fed's attachment to interest rate targeting in one form or another [Goodfriend (1991)]. They argue that innovations to monetary aggregates, such as M1, the adjusted monetary base or total reserves, reflect shocks to money demand rather than to money supply. Consequently, the inability of researchers to isolate a statistically significant and economically relevant liquidity effect stems from their failure to correctly identify the exogenous policy actions of the Fed.

Recently, Christiano and Eichenbaum (1991, 1992b), Christiano, Eichenbaum and Evans (1994a,b) and Strongin (1995) have argued that nonborrowed reserves reflect the exogenous policy actions of the Fed.[2] Using nonborrowed reserves and Vector autoregression (VAR), they find a liquidity effect that is both statistically significant and economically important. Recently, however, Pagan and Robertson (1995) and Christiano (1995) have shown that the liquidity effect identified in this way vanishes after the early 1980s.

This paper shows that there is an identification problem associated with using nonborrowed reserves as an indicator of monetary policy and shows how changes in the demand

---

See Thornton (1988b), Reichenstein (1987) and Pagan and Robertson (1995).

[2]Since Christiano and Eichenbaum use a VAR methodology, it is more precisely correct to say that they use exogenous shocks to nonborrowed reserves. Most of their empirical work, however, is motivated by a simple statistical analysis of the relationship between nonborrowed reserves and the funds rate. I take the same liberty later and initially focus on the relationship between nonborrowed reserves and the funds rate. Later the analysis focuses on shocks to nonborrowed reserves using a VAR model similar to that of Christiano and Eichenbaum (1991, 1992b) and Christiano, Eichenbaum and Evans (1994a,b).

for borrowed reserves can be used to identify the liquidity effect using nonborrowed reserves. Specifically, it shows how the negative relationship between nonborrowed reserves and the federal funds rate may result from either the presence or absence of a liquidity effect.[3] Furthermore, it shows how changes in the demand for borrowed reserves can be used to identify which of these alternatives account for the relationship between nonborrowed reserves and the funds rate.

The evidence presented here suggests that the negative association between nonborrowed reserves and the funds rate that Thornton (1988a), Christiano and Eichenbaum (1991, 1992a,b), Christiano, Eichenbaum and Evans (1994a,b), Strongin (1995) and Pagan and Robertson (1995) report, stems from the absence, rather than the presence, of a statistically significant and economically important liquidity effect. Also, the evidence suggests that the liquidity effect did not change in the early 1980s, as Pagan and Robertson (1995) and Christiano (1995) suggest, but rather that it never existed.

I. *Nonborrowed Reserves, Borrowing and the Liquidity Effect*

The liquidity effect associated with nonborrowed reserves is motivated by the market for reserves. The demand for reserves is derived from reserve requirements imposed on certain deposit liabilities of banks.[4] Banks' demand for such deposits is assumed to be inversely related to a short-term interest rate, i, representing the opportunity cost of holding such deposits. Hence, so too is banks' demand for reserves. That is,

---

[3]This point has also been made by Coleman, Gilles and Labadie (1995).

[4]Note that the demand for something called *reserves* likely would arise endogenously if reserve requirements were not imposed by the Fed. In this case, however, the nature of reserves and their relationship to bank liabilities might be quite different from those imposed by the central bank.

$$(1) \quad R^d = \tau f(i), \quad f' \leq 0,$$

where f(i) denotes the demand for reservable bank liabilities and τ denotes the marginal reserve requirement. For convenience assume that reserves are congruent with the monetary base and arise from two sources, the Federal Reserve's holdings of government debt, B_f, and borrowed reserves, BR.[5] Hence,

$$(2) \quad R^s = BR + B_f .$$

Borrowed reserves are supplied when the Fed makes loans to banks at the discount window. The demand for borrowed reserves depends on the spread between the federal funds rate, i_f, and the discount rate, i_d, and on other factors, β.[6] That is,

$$(3) \quad BR = \beta + h(i_f - i_d), \quad h' \geq 0; \quad \beta \geq 0.$$

Equations 1, 2 and 3 are combined to obtain the reserve market equilibrium condition,

$$(4) \quad \tau f(i) = B_f + \beta + h(i_f - i_d).$$

To close what can be thought of as the reserve block of the credit market it is necessary to have a relationship that links the federal funds rate and the short-term interest rate. For this

---

[5]In this model, changes in nonborrowed reserves are congruent with open market operations; however, this is not true in a model that allows for other sources of reserves.

[6]The degree of administration of the discount window has changed over time. See Goodfriend (1983), Thornton (1986) and Cosimano and Sheehan (1994) for discussions of the discount window.

purpose, we assume the following condition holds,

$$(5) \quad \theta(i_f\,,\, i) = 0,$$

where θ_1 and θ_2 are opposite in sign, so that $di_f/di = -\theta_2/\theta_1 > 0$. Equation 5 can be thought of as an arbitrage condition and implies nothing about the causality between the rates.[7]

The reserve block has three endogenous variables, i_f, i, and B_f, but only two equations. Causality is established by assuming one of the variables is exogenous with respect to the others. In many discussions of monetary policy [Bernanke and Blinder (1992), Cook and Hahn (1989), Laurent (1988) and Goodfriend (1991)] attention is focused on shocks to the funds rate *causing* changes in other interest rates. This causal ordering is imposed by assuming that i_f, or equivalently B_f, is exogenous. Since policy is implemented through open market operations, B_f will be taken to be exogenous.[8] The resulting liquidity effect is

$$(6) \quad \partial i/\partial B_f = \theta_1(\theta_1\tau f\,' + \theta_2 h')^{-1}.$$

Note that $f\,' < 0$ is insufficient for a liquidity effect. For example, if the discount window were *open*, banks would be free to meet their reserve demand at the discount window, the exogenous decline in reserves would be offset by an endogenous rise in borrowing, i.e., $h' \rightarrow \infty$

---

[7]Equation 5 could be thought of as the expected value of an arbitrage condition that must hold on average, i.e., $\theta(i_f, i) = \epsilon$, where the $E(\epsilon) = 0$. Note too that the function θ need not be linear. If it were, however, Equation 5 could be thought of as a cointegration relationship. There is some evidence that the federal funds rate and short-term interest rates, like the 3-month T-bill rate, are cointegrated, e.g., Garfinkel and Thornton (1995).

[8]The results are the same whether i_f or B_f is taken to be exogenous. If the funds rate is exogenous then B_f must change endogenously by the amount required to change the funds rate target by the desired amount. Indeed, Bernanke and Blinder (1992) report that the results are similar whether shocks to the funds rate or shocks to nonborrowed reserves are taken as the indicator of monetary policy.

implies that $\partial i/\partial B_f = 0$.[9]

This result stems from the fact that an open market operation that fails to change total reserves cannot affect interest rates. After accounting for the effect of borrowed reserves, nonborrowed and total reserves contain the same information relevant for identifying the liquidity effect. That an empirically important liquidity effect can be identified only using nonborrowed reserves is, *prima facie,* a reason to question whether it is the liquidity effect that has been identified.[10]

A. *The Relationship Between Nonborrowed Reserves and Interest Rates When There Is No Liquidity Effect*

Now consider the relationship between nonborrowed reserves and the federal funds rate when there is no possibility for a liquidity effect. Assume that short-term interest rates are exogenous to Fed actions [Coleman, Gilles and Labadie (1995)].[11] This assumption means the relationship between nonborrowed reserves and the federal funds rate is determined by how the Fed reacts to exogenous changes in interest rates. This can be determined by differentiating the reserve market equilibrium condition, which yields the Fed's reaction function, namely,

$$(7) \quad dB_f/di = (\theta_1 \tau f' + \theta_2 h')\, \theta_1^{-1}.$$

[9]The responsiveness of discount window borrowing to policy induced changes in the interest rate played a central role in the so-called *free reserves* controversy [e.g., Meigs (1962)] and the difference of opinion between Friedman (1960) and Samuelson (1960) about the relevancy of the discount window to the conduct of monetary policy.

[10]Hence, the fact that Christiano and Eichenbaum (1991) find a positive association between total reserves and the federal funds rate is itself *prima facie* evidence against the liquidity effect. This observation also has been made by Coleman, Gilles and Labadie (1995).

[11]Coleman, Gilles and Labadie (1995) assume there is no causal relationship between open market operations and interest rates. In their model, however, $i = i_f$. Hence, they assume that the interest rate is determined independent of discount window operations or the supply of reserves. In this model, however, the funds rate is determined independently of the short-term interest rate, subject only to the arbitrage condition. Thornton (1993) argues that the Fed's influence on the supply of credit is exaggerated by its presence in the funds market. Granger causality tests in Garfinkel and Thornton (1995) suggest that neither the federal funds or three-month bill T-rates satisfy the necessary conditions for causality running from one rate to the other. Consequently, it would appear that either of the characterizations presented above may be extreme.

A sufficient condition for the absence of a liquidity effect is $f' = 0$. In this case, Equation 7 can be rewritten as,

$$(8) \quad dB_f / di = (\theta_2/\theta_1)h' < 0.$$

In the absence of a liquidity effect, the negative association between interest rates and nonborrowed reserves stems directly from the Fed offsetting interest-induced changes in borrowing. This is plausible because the Trading Desk of the Federal Reserve Bank of New York estimates the demand for reserves and each day supplies the reserves it believes are necessary to meet the demand. Estimates of reserve demand are slow to change, while information on the previous day's borrowing is available each day. Therefore, there may be a tendency for the Fed to adjust to changes in borrowing in an attempt to supply the projected level of reserves demanded. Moreover, the Fed has followed this procedure whether it was targeting the federal funds rate or nonborrowed reserves. Consequently, it should be invariant across time.

II. Identifying the Liquidity Effect Through the Demand for Borrowed Reserves

The above analysis shows that evidence about whether the relationship between the federal funds rate and nonborrowed reserves is due to the presence or absence of the liquidity effect can be obtained by seeing how the relationship changes with changes in the demand for borrowed reserves. If the relationship between the federal funds rate and nonborrowed reserves is due to a liquidity effect, it will become stronger the smaller is h'. Indeed, the liquidity effect is largest when $h' = 0$, or alternatively, if the discount window were closed.[12]

[12]Indeed, this is the reason that Friedman (1959) advocated closing the discount window.

Conversely, if the negative relationship between nonborrowed reserves and the funds rate is due to the absence of the liquidity effect, Equation 8 indicates that the association between nonborrowed reserves and the funds rate will become weaker, the smaller is h'. Indeed, there would be no relationship if the discount window were closed.

A. The Data

The data are monthly and cover the period 1959.1 to 1993.12. The federal funds rate, FF, is a weighted average of rates on daily transactions for a group of federal funds brokers who report to the Federal Reserve Bank of New York. The discount rate, DR, is the rate that is in effect from the day that discount rate changes are first announced. Because of the emphasis the Fed places on seasonal plus adjustment borrowing in its daily operating procedure, the commonly used measure of nonborrowed reserves – total reserves, adjusted for reserve requirement changes, less seasonal and adjustment borrowing – is used. The current practice of classifying borrowing into *extended credit*, *seasonal* and *adjustment* borrowing began in May 1973. Prior to that, all borrowing was adjustment borrowing.

B. The Demand for Borrowed Reserves

Although it has received relatively little attention [Clouse (1992, 1994) and Thornton (1986)], the demand for borrowed reserves has changed significantly. Figure 1 shows monthly levels of adjustment and seasonal borrowing and the spread of the federal funds rate less the discount rate.[13] There are several interesting features of these data. First, during the period prior to the mid-1960s the spread between the federal funds and discount rate was generally negative

[13]These data have been adjusted for two factors. The first was the adjustment borrowing by Continental Illinois in May and June of 1984 that was initially classified as extended credit borrowing. The second is the $22.6 billion overnight borrowing by the Bank of New York on November 21, 1985. However, these adjustments do not alter the qualitative conclusions reached in this paper.

and the level of borrowing was small. The discount window was *open* in the sense that a bank who wished to borrow obtained funds. Regulation A, which governed discounts and advances, stated that borrowing at the window was a privilege of membership and not a right and that borrowing to make a profit, by re-lending at a higher rate, was expressly forbidden. The Fed argued that banks were *reluctant to borrow*, but it is unclear whether their reluctance was inherent or induced by administrative oversight. In any event, when the funds rate reached the level of the discount rate, banks would turn to the discount window. Consequently, the discount rate was an effective ceiling for the funds rate. In the mid-1960s, however, the administration of the discount window changed. Requests to borrow were sometimes denied. From that period forward, the funds rate generally traded above the discount rate.

Second, it is clear that the importance of adjustment borrowing has shifted dramatically in the last decade or so, both absolutely and relative to seasonal borrowing. For example, the ratio of seasonal to adjustment borrowing was only 0.048 during the first year of the new program, compared with 2.128 during the final year of the sample. Finally, there are marked changes in relationship between the spread and adjustment borrowing over the period.

Because of the marked difference in the demand for seasonal and adjustment borrowing and the marked change in the composition of seasonal plus adjustment borrowing, attention is focused on adjustment borrowing. To investigate changes in the behavior of adjustment borrowing, the following equation,

$$(12)\quad AB_t = \delta_0 + \delta_1 sp_t + \delta_2 sp_t^2 + \epsilon_t \,,$$

was estimated. The spread between the federal funds and discount rates, i.e., FF-DR, is denoted sp. The squared spread is included to capture potential nonlinearities in the borrowing function [Polakoff (1960), Clouse (1990) and Peristiani (1991)]. To see how well the economic variables explain the behavior of adjustment borrowing, estimates of Equation 12 are compared with those of a simple univariate time-series model of borrowing,

$$(13)\quad AB_t = \delta_0 + \epsilon_t,$$

where $\epsilon_t = \theta(L)\epsilon_{t-1} = u_t$ and where $\theta(L)$ is the polynomial, $\theta_0 + \theta_1 L + \theta_2 L^2 + \ldots + \theta_k L^k$, in the lag operator, L, i.e., $L\epsilon_t = \epsilon_{t-1}$.

Estimates of Equations 12 and 13 are presented in Table 1 for several sample periods, along with estimates of an equation that encompasses them. A brief description of why these periods were chosen and the average level of adjustment borrowing during each is presented at the bottom of the table. The importance of economic variables in determining the level of borrowing changed significantly over the period. During the period when the discount rate was an effective ceiling for the federal funds rate, the economic variables explain relatively little of adjustment borrowing and are dominated by the time-series model. The economic variables become more important in explaining the behavior of adjustment borrowing during the next two periods and the economic variables dominate the time-series model during the periods that span 1977.9 to 1984.6. After 1984.6, very little of the behavior of adjustment borrowing is explained by either the economic or time-series model.

If the relationship between nonborrowed reserves and interest rates is due to the liquidity effect, it should be the strongest during the first period and the last two periods and the weakest during the periods from 1965.3 to 1984.6. If the relationship is due to the definition connecting nonborrowed to borrowed reserves and the interest responsiveness of borrowing, however, it should be the strongest during the middle periods and the weakest during the early and latter periods.

C. *Prima Facie Evidence*

Before turning to the VAR analysis, it is instructive to see what relatively simple analyses suggest about the relative merits of the alternative hypotheses. First, we note that if the negative association between nonborrowed reserves and the funds rate is due to the interest sensitivity of borrowing, there should be a strong negative association between ΔNBR and ΔAB and that this relationship should have broken down in recent years, as adjustment borrowing has become smaller and less interest sensitive. That this is exactly what happens is shown in Figure 2, which shows 60-month moving correlations between ΔFF and ΔNBR and -ΔBR, respectively. Not only is there a very close correspondence between these correlations, but the correlation between the fund rate and NBRs falls off dramatically in mid-1984, as does the correlation between the funds rate and adjustment borrowing.

It was argued previously that the Fed operates in such a way as to offset changes in seasonal plus adjustment borrowing. This would be true of all changes in borrowing, even those that are not associated with changes in the rate spread. To investigate this, the equation,

$$(14) \quad \Delta NBR_t = \delta_0 + \delta_1 \Delta sp_t + \delta_2 \Delta sp_t^2 + \delta_3 \Delta(AB + SB)_t + \epsilon_t,$$

was estimated. Estimates of Equation 14 are presented in Table 2 for the entire sample and the previously-used sample periods. Estimates of δ_3 are negative over the entire period and for each of the sample periods. Moreover, generally they are not significantly different from -1.

Furthermore, as might be expected if the definition hypothesis is correct, the adjusted R^2 are generally larger during the periods when the economic variables explain adjustment borrowing rather well. In any event, the fact that estimates of δ_3 are very close to, and frequently not significantly different from -1, supports the notion that, at a monthly frequency at least, the Fed tends to offset nearly all of the change in seasonal plus adjustment borrowing. Moreover, it appears that the Fed essentially behaved this way during the entire period.

Given this result, it is important to see whether there is a significant relationship between nonborrowed reserves and the funds rate, conditional on the relationship between borrowing and nonborrowed reserves. If the relationship between nonborrowed reserves and the funds rate is due to the definition linking borrowed and nonborrowed reserves, then adding borrowed reserves to a regression of the funds rate on nonborrowed reserves, should eliminate the connection to nonborrowed reserves. Consequently, the equation,

$$(15)\quad \Delta FF_t = \mu_0 + \mu_1 \Delta NBR_t + \mu_2 \Delta AB_t + \mu_3 \Delta SB_t + \epsilon_t,$$

was estimated, with and without the restrictions $\mu_2 = \mu_3 = 0$ and with and without $\epsilon_t = \theta\epsilon_{t-1} + u_t$. The results, reported in Table 3, show that when the change in borrowing is included, the strong contemporaneous negative relationship between nonborrowed reserves and the funds rate disappears. Again, these results are consistent with the definition, but not the liquidity effect, hypothesis.

III. *VARs And the Identification of Monetary Policy*

While some may find the *prima facie* evidence convincing, others will not. They will contend that the above results merely show that there is a significant, negative contemporaneous correlation between borrowed and nonborrowed reserves which makes it difficult to identify the effect of changes in nonborrowed reserves on the funds rate. They will argue that this points to the need to identify exogenous shocks to jointly-determined endogenous variables like borrowing and NBR using a systems approach.[14] In particular, it is important to identify exogenous policy innovations that could result in a liquidity effect.

A. Monetary Policy and VAR Innovations

Christiano and Eichenbaum (1991, 1992a,b) and Christiano, Eichenbaum and Evans (1994a,b) argue that they have identified structural policy shocks by imposing a particular Wold causal ordering on a VAR model that utilizes nonborrowed reserves as the monetary policy variable. Their identification criterion is whether or not other variables in the system respond to a policy innovation in a manner consistent with economic theory. Specifically, they argue that the Cholesky decomposition that they have chosen identifies policy shocks because innovations to NBR initially reduce the funds rate, raise output, increase total reserves and so on and so forth.

B. The VAR Evidence

This section presents evidence from the VAR model of Christiano, Eichenbaum and Evans (1994a,b) as modified by Pagan and Robertson (1995). Pagan and Robertson's preferred model has six variables: real GDP, Y, the price level, P, the commodity price index, CP, nonborrowed reserves, NBR, the federal funds rate, FF, and total reserves, adjusted for reserve

---

[14]Note that because of the definition, NBR = TR - BR, there are at most two independent shocks to these three variables.

requirement changes, TR. In their specification all variables except FF are in logs. However, using logs distorts the linear relationship between total, borrowed and nonborrowed reserves. Hence, in the analysis that follows, all variables are in levels. In addition, borrowed reserves is used in place of total reserves. [The appendix shows that the use of non-log data and the substitution of borrowed for total reserves has virtually no effect on Pagan and Robertson's results.] Following Pagan and Robertson, 14 lags were used when the VARs were estimated over the entire period. When the VARs were estimated over shorter samples, the lag order was six.

Figure 3 shows three IRFs based upon estimates over the entire sample period, two for innovations to nonborrowed reserves to the federal funds rate from two different causal orderings. The one analogous to that used by Pagan and Robertson {Y, P, CP, NBR, FF, BR} is black, here and elsewhere. The IRF when borrowed reserves precedes NBR, i.e., {Y, P, CP, BR, NBR, FF}] is red, and the IRF when the positions of borrowed and nonborrowed reserves are switched, i.e., {Y, P, CP, BR, FF, NBR}, is blue. The 90 percent confidence bands for the Pagan and Robertson ordering are presented as black dashed lines.

The IRF for the ordering used by Pagan and Robertson is nearly identical to the one they report, and suggests a statistically significant and economically important liquidity effect. However, when BR precedes NBR in the Cholesky ordering the results change dramatically; the liquidity effect for NBR all but disappears. Furthermore, IRF of NBR→FF for the Pagan-Robertson ordering is essentially the mirror image of the IRF of BR→ FF when the Cholesky ordering is {Y, P, CP, BR, FF, NBR}.

These results suggest the possibility that the effect of an innovation to NBR on the funds rate is due to the definition which links these reserve measures rather than to the liquidity effect. These results should not be taken as evidence against the liquidity effect, however. The sensitivity of the IRFs to changes in the causal ordering merely suggests that there is a contemporaneous correlation between borrowed and nonborrowed reserves that is not accounted for by imposing a recursive structure. Moreover, the fact that the IRF of BR→ FF is the mirror image of NBR→ FF when the positions of these variables in the ordering is swapped, merely demonstrates that an increase in nonborrowed reserves has the same effect on the funds rate as an upward shift in the borrowing function, i.e., an increase in β in Equation 3. This is required by the reserve model.

How can the IRFs be used to identify the liquidity effect? Christiano, Eichenbaum and Evans (1994a,b) suggest that identification can be achieved by seeing whether the other IRFs from NBR behave in a manner consistent with their perception of how money affects economic activity. Given the apparent lack of agreement and understanding of how monetary policy impulses are transmitted through the economy, however, this would not seem to be a useful, objective identifying criterion.[15] For one thing, it would lead those who believe that monetary policy actions are transmitted to the economy through their effect on interest rates to dismiss specifications that do not produce a liquidity effect.[16]

In any event, this criterion is not useful in this instance because the IRFs for different causal orderings are very similar. Figures 4 - 6 show all of the 36 IRFs for the three Cholesky orderings in Figure 3. BR has been replaced with -BR, so that the IRFs for NBR and BR can be

---

[15]For example, see the conference proceedings of the Federal Reserve Bank of St. Louis ([Federal Reserve Bank of St. Louis (1995).

[16]It is well known that different Cholesky orderings can give rise to quite different IRFs. It is also well known that there are many competing theories of how monetary policy affects the economy. Consequently, it is difficult to see how this approach of identification can be of use.

compared more easily. A comparison of row three in Figures 4 and 5 shows that the response of output, prices, and commodity prices to innovations in -BR or NBR are very similar. While Figure 6 shows that having -BR precede NBR in the Cholesky ordering alters the effect of an innovation to NBR on Y, P and CP, the results are closer to what theory would suggest, i.e., output and prices initially rise, but are not affected in the long run. The response that is most severely damaged by the changing the Cholesky ordering is the liquidity effect.

The identifying criterion suggested here is to see whether the IRF for NBR → FF changes over periods of changes in the demand for borrowed reserves in a manner consistent or inconsistent with the liquidity effect hypothesis. If the IRF suggests that the liquidity effect is larger and more persistent during periods when borrowing is small and relatively interest insensitive and smaller during periods when borrowing is large and relatively interest sensitive, one can conclude that the IRFs reflect a liquidity effect. If, however, the reverse is true, one must conclude that the relationship is largely definitional.

IRFs for various periods corresponding to the periods presented in Table 1 are presented in Figures 7 - 11. In every case, the general results discussed for the three IRFs based on the entire period are replicated for each of the shorter periods. More important for identifying the liquidity effect, however, the IRFs for NBR based on the Pagan and Robertson causal ordering reveal a very small and statistically insignificant liquidity effect during periods when borrowing was small and interest insensitive: 1959.1-1965.2 [Figure 7] and 1984.6-1993.12 [Figure 11]. The "liquidity effect" is large and statistically significant only during periods when the relationship between adjustment borrowing and the spread between the funds and the discount rates is relatively strong [Figures 8-10]. Indeed, the IRFs suggest that the relationship between

NBR and the funds rate is the strongest during the period when the economic model dominates the time-series model of borrowed reserves [Figure 10]. The results in Figures 7 - 11 are consistent with the definition hypothesis of the relationship between NBR and the funds rate, but not with the liquidity effect hypothesis. Indeed, the evidence suggests that the innovations to nonborrowed reserves reflect the Fed's attempt to offset the effect of changes in the demand for borrowed reserves. Innovations to nonborrowed reserves when borrowing is small result in a small and spastically insignificant change in the funds rate. Thus, the evidence suggests that the liquidity effect is nil.

IV. Summary and Conclusions

The liquidity effect is thought to play a prominent role in the transmission of monetary policy actions to the economy despite the fact that, until very recently, the empirical support for it was scant. Recently, Christiano and Eichenbaum (1992ab), Christiano, Eichenbaum and Evans(1994ab) and Strongin (1995) and Pagan and Robertson (1995) have reported finding a statistically significant and economically relevant liquidity effect using nonborrowed reserves. This paper investigates the liquidity effect using nonborrowed reserves as the indicator of monetary policy, pointing out that the negative relationship between nonborrowed reserves and the federal funds rate found in the data could be due either to the existence or absence of the liquidity effect. We then point out that it is possible to differentiate between these alternative explanations of the data by seeing how the relationship between nonborrowed reserves and the federal funds rate varies with shifts in the demand for borrowed reserves. Specifically, if the negative association between nonborrowed reserves and the funds rate is due to the liquidity effect, it should get stronger the smaller and less interest sensitive the demand for borrowed reserves. Alternatively, if the relationship is due to an absence of a liquidity effect and the definition that links nonborrowed to borrowed reserves, it should get weaker the smaller and less interest sensitive the demand for borrowed reserves.

Both relatively simple single-equation statistical analyses and systems VAR evidence suggests that the negative association between the funds rate and nonborrowed reserves varies positively with the interest sensitivity of borrowing. These results suggest that the liquidity effect is weak and perhaps nil, even when nonborrowed reserves are used as the indicator of monetary policy. Hence the failure to find evidence of a liquidity effect does not depend on the monetary variable used to proxy for monetary policy shocks as Pagan and Robertson (1995) suggest. There is little evidence of a liquidity effect if the monetary base, M1, total reserves or nonborrowed reserves are used as the monetary policy indicator.

In addition, the results presented here suggest that the puzzle of the vanishing liquidity effect since the early 1980s, that Pagan and Robertson (1995) reported and Christiano (1995) confirmed, is really a puzzle about why banks have shunned the discount window since the mid-1980s. Clouse (1990, 1994) has suggested that the dramatic shift in banks' demand for borrowed reserves is due to an increase in the reluctance of large institutions to be seen at the discount window in the wake of the large discount window borrowing by Continental Illinois. While this explanation may be incomplete, the timing of the dramatic decline in the demand for adjustment borrowing coincides with the problem bank's very large borrowing at the discount window.

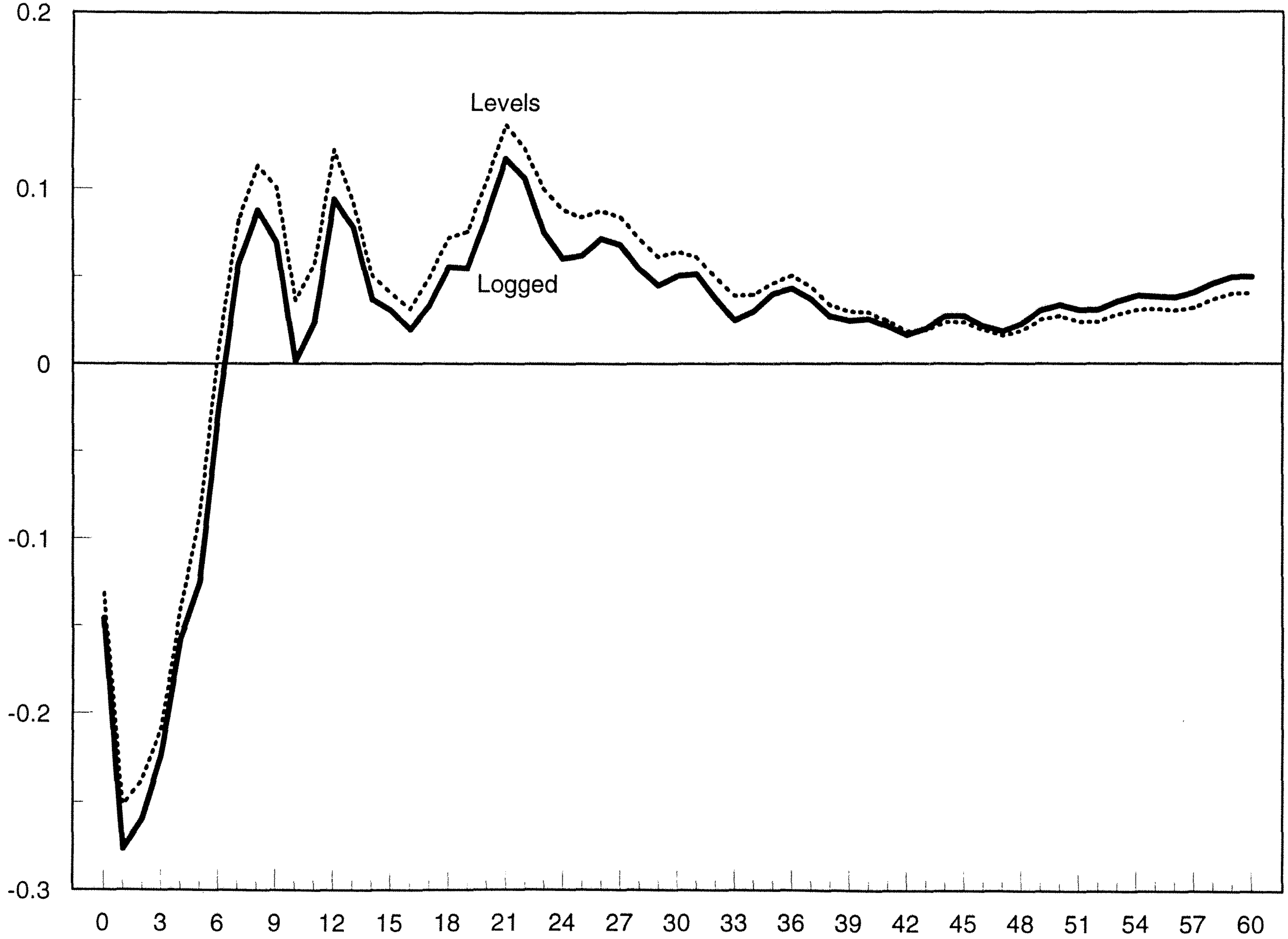
APPENDIX

The purpose of this appendix is to show that Pagan and Robertson's (1995) results are not significantly affected when two modifications are made. This first is to replace the logged variables with variables in levels. The second is to replace total reserves with borrowed reserves. The first is done by comparing the IRFs for NBR → FF using both logged and level data where the Cholesky ordering is {Y, P, CP, NBR, FF, TR}, presented in Figure A.1. While only the results for the IRFs for NBR→FF are presented here, the results hold up for all possible IRFs which these models generate.

The second is done by comparing the IRFs for NBR → FF using level data and alternative models using TR and BR. A comparison of these IRFs is not presented because they were identical. While initially surprised by this result, further reflection suggests that it is a necessary consequence of the fact the definition, NBR = TR - BR, means that there are at most two independent innovations to these three variables. The system with NBR and TR contains the same information as the systems with either NBR and BR or TR and BR.

Figure A1: IRFs NBR --> FF {Y,P,CP,NBR,FF,TR}

1959.1 - 1993.12



REFERENCES

Bernanke, Ben S. and Alan S. Blinder. "The Federal Funds Rate and the Channels of Monetary Transmission," *American Economic Review* (September 1992), 901-21.

Bernanke, Ben S. and Ilian Mihov. "Measuring Monetary Policy," NBER working paper no. 5145, 1995.

Cagan Phillip and Arthur Gandolfi. "The Lag in Monetary Policy as Implied by the Time Pattern of Monetary Effects on Interest Rates," *American Economic Review* (May 1969), 277-84.

Christiano, Lawrence J. "Commentary," Federal Reserve Bank of St. Louis *Review* (May/June 1995), 55-61.

Christiano, Lawrence J. and Martin Eichenbaum. "Identification and the Liquidity Effect of a Monetary Policy Shock," NBER working paper No. 3920, November 1991.

______. "Liquidity Effects and the Monetary Transmission Mechanism," *American Economic Review* (May 1992a), 346-53.

______. "Identification and the Liquidity Effects of Monetary Shocks," in *Business Cycles, Growth and the Political Economy*, eds. Cukierman, Hercowitz and Leiderman, MIT Press, 1992b.

Christiano, Lawrence J., Martin Eichenbaum and Charles L. Evans. "The Effects of Monetary Policy Shocks: Evidence From the Flow of Funds," Federal Reserve Bank of Chicago Working Paper Series, WP-94-2, March 1994a.

______. "Identification and the Effects of Monetary Policy Shocks," Federal Reserve Bank of Chicago Working Paper Series, WP-94-7, May 1994b.

Clouse, James A. "Recent Developments in Discount Window Policy," *Federal Reserve Bulletin* (November 1994), 965-77.

______. "Arriving at the Window: An Analysis of the Slowdown in the Number of Adjustment Credit Borrowers," Board of Governors of the Federal Reserve System, working paper, 1992.

Coleman, John, Christian Gilles and Pamela Labadie. "A Model of the Federal Funds Market," forthcoming, *Journal of Economic Theory* (1995).

Cook, Timothy and Thomas Hahn. "The Effects of Changes in the Federal Funds Rate Target on Market Interest Rates," *Journal of Monetary Economics* (September 1989), 331-51.

Cosimano, Thomas F. and Richard G. Sheehan. "Is the Conventional View of Discount Window Borrowing Consistent with the Behavior of Weekly Reporting Banks?," *Review of Economics and Statistics* (November 1994, 761-70..

Dhrymes, Phoebus J. *Introductory Econometrics*. New York: Springer-Verlag, 1978.

Federal Reserve Bank of St. Louis, "Channels of Monetary Policy: Proceedings of the Nineteenth Annual Economic Policy Conference of the Federal Reserve Bank of St. Louis," Federal Reserve Bank of St. Louis *Review* (May/June 1995).

Friedman, Milton. *A Program for Monetary Stability*. New York: Fordhan University Press, 1960.

Garfinkel, Michelle R. and Daniel L. Thornton. "The Information Content of the Federal Funds Rate: Is It Unique?," *Journal of Money, Credit and Banking* (August 1995), pp. 838-47.

Goldfeld, Stephen M. and Edward J. Kane. "The Determinants of Member Bank Borrowing: An Econometric Study," *Journal of Finance* (September 1966), 499-514.

Goodfriend, Marvin. "Interest Rates and the Conduct of Monetary Policy," *Carnegie-Rochester Conference Series on Public Policy* Vol 34, (Spring 1991), 7-30.

_______. "Discount Window Borrowing, Monetary Policy, and the Post October 6, 1979 Federal Reserve Operating Procedure," *Journal of Monetary Economics* (September 1983), 343-56.

Laidler, David. "The Buffer Stock Notion of Monetary Economics," *Conference Proceedings, Supplement to the Economic Journal* (March 1984), 17-34.

Laurent, Robert P. "An Interest-Rate Based Indicator of Monetary Policy," Federal Reserve Bank of Chicago *Economic Perspectives* (January/February 1988), 3-14.

Leeper, Eric M. and David B. Gordon. "In Search of the Liquidity Effect," *Journal of Monetary Economics* (June 1992), 341-69.

Meigs, A. James. *Free Reserves and the Money Supply*. Chicago: University of Chicago Press, 1962.

Melvin, Michael. "The Vanishing Liquidity Effect on Money on Interest: Analysis and Implications for Policy, *Economic Inquiry* (April 1983), 188-202.

Pagan, Adrian R. and John C. Robertson. "Resolving the Liquidity Effect," Federal Reserve Bank of St. Louis *Review* (May/June 1995), 33-54.

Peristiani, Stavros. "The Model Structure of Discount Window Borrowing," *Journal of Money, Credit and Banking* (February 1991), 13-34.

Polakoff, Murry E. "Reluctance Elasticity, Least Cost and Member-Bank Borrowing: A Suggested Integration," *Journal of Finance* (March 1960), 1-18.

Reichenstein, William. "The Impact of Money on Short-Term Interest Rates," *Economic Inquiry* (January 1987), 67-82.

Samuelson, Paul A. "Reflections on Monetary Policy," *Review of Economics and Statistics* (August 1960), 263-69.

Sims, Christopher A. And Tao Zha. "Does Monetary Policy Generate Recessions?," unpublished manuscript, September 1995.

Strongin, Steven. "The Identification of Monetary Policy Disturbances: Explaining the Liquidity Puzzle," *Journal of Monetary Economics* (June 1995), 463-97.

Thornton, Daniel L. "The Borrowed-Reserves Operating Procedure: Theory and Evidence," Federal Reserve Bank of St. Louis *Review* (January/February 1988a), 30-54.

________. "The Effect of Monetary Policy on Short-Term Interest Rates," Federal Reserve Bank of St. Louis *Review* (May/June 1988b), 53-72.

________. "The Discount Rate and Market Interest Rates: Theory and Evidence," Federal Reserve Bank of St. Louis *Review* (August\September 1986), 5-21.

________. "Comments on Federal Reserve Operating Procedures and Institutional Change," *Operating Procedures and the Conduct of Monetary Policy: Conference Proceedings*, Marvin Goodfriend and David H. Small, eds., Financial and Economics Discussion Series, Working Series 1: Part 2, (March 1993).

Table 1: Estimate of the Demand for Borrowed Reserves

	59.1 - 65.2			65.3 - 73.4			73.5 - 77.8			77.9 - 80.12			81.1 - 84.6			84.7 - 89.12			90.1 - 93.12		
	OLS	AR(1)	GLS	OLS	AR(1)	GLS	OLS	AR(1)	GLS	OLS	AR(1)	GLS	OLS	AR(1)	GLS	OLS	AR(1)	GLS	OLS	AR(1)	GLS
Const.	0.468* (12.16)	0.395* (2.34)	0.420* (2.73)	0.418* (15.86)	0.734* (2.83)	0.500* (4.77)	0.362* (11.31)	1.042 (1.93)	0.618* (2.93)	0.727* (12.42)	1.005* (5.82)	0.737* (8.96)	0.357* (6.85)	0.824* (5.63)	0.351* (5.37)	0.352* (6.36)	0.327* (11.70)	0.298* (4.16)	0.071* (2.20)	0.132* (4.49)	0.070 (1.95)
SP	0.747* (3.86)		0.207* (2.89)	0.398* (9.14)		0.282* (4.70)	0.528* (13.39)		0.361* (5.36)	0.392* (7.07)		0.381* (5.75)	0.365* (6.59)		0.376* (6.02)	-0.063 (0.63)		0.030 (0.25)	0.121 (0.70)		0.133 (0.71)
SP^2	0.309* (2.31)		0.069* (2.03)	-0.039* (2.29)		-0.011 (0.59)	-0.043* (3.44)		-0.031* (2.35)	-0.029* (2.46)		-0.032* (2.27)	-0.028* (2.72)		-0.031* (2.83)	0.023 (0.68)		-0.003 (0.08)	0.027 (0.21)		0.017 (0.12)
θ		0.969* (33.54)	0.967* (32.73)		0.951* (30.43)	0.877* (18.10)		0.968* (27.96)	0.921* (17.03)		0.612* (4.89)	0.366* (2.49)		0.721* (6.74)	0.280 (1.89)		0.324* (2.78)	0.345* (2.99)		0.320* (2.34)	0.124 (0.86)
$\bar{R}^2$	0.282	0.950	0.955	0.674	0.856	0.888	0.925	0.932	0.959	0.672	0.359	0.703	0.777	0.516	0.789	-0.024	0.087	0.064	0.195	0.081	0.189
DW	0.113			0.373			0.679			1.280			1.409			1.355			1.738		
Encompassing Tests																					
OLS/ AR(1)	994.39*			143.37*			26.32*			2.64			2.12			9.65*			0.54		
AR(1)/ OLS	2.96			5.71*			8.89*			21.04*			24.84*			0.001			4.04*		

*Indicates significance at the 5 percent level. Absolute value of t-statistics in parentheses.

1959.1 - 65.2: Period when the discount window was "open" in that banks that came to the window with the required collateral were not refused loans. During this period, the discount rate was an effective ceiling for the federal funds rate. The average level of adjustment borrowing was $0.326 billion.

1965.3 - 73.4 End of "open" discount window policy to the beginning of the seasonal and extended credit borrowing programs. The average level of adjustment borrowing was $0.605 billion.

1973.5 - 77.8 Beginning of seasonal and extended credit borrowing programs to the beginning of a rapid increase in the use of the discount window for adjustment borrowing. The average level of adjustment borrowing was $0.646 billion.

1977.9 - 80.12 Period of very high average level of adjustment borrowing. The average level of adjustment borrowing was $1.002 billion.

1981.1 - 84.6 Period ends with a dramatic decline in adjustment borrowing relative to the spread between the federal funds rate and the discount rate first suggested by Clouse (1990). The average level of adjustment borrowing was $0.792 billion.

1984.7 - 89.12 This period begins and ends with what appear to be dramatic declines in the use of the discount window for adjustment borrowing. The average level of adjustment borrowing was $0.326 billion.

1990.1 - 93.12 This period begins with what appears to be a significant drop in the use of the discount window for adjustment purposes. The average level of adjustment borrowing was $0.131 billion.

Table 2: Estimate of Equation 14

	Period							
	59.1 - 93.12	59.1 - 65.2	65.3 - 73.4	73.5 - 77.8	77.9 - 80.12	81.1 - 84.6	84.7 - 89.12	90.1 - 93.12
Const.	0.118* (5.83)	0.011 (0.92)	0.048* (3.99)	0.044* (2.25)	0.070 (1.99)	0.097 (1.31)	0.232* (3.39)	0.421* (3.86)
ΔSP	0.048 (1.02)	-0.172 (1.90)	-0.029 (0.49)	0.155 (1.87)	0.019 (0.30)	0.096 (0.42)	0.643 (1.83)	0.214 (0.36)
ΔSP^2	-0.004 (0.39)	-0.059 (1.44)	0.035* (2.09)	-0.012 (0.93)	0.003 (0.25)	-0.015 (0.51)	-0.108 (0.87)	0.073 (0.15)
ΔTB	-0.760* (10.45)	-0.819* (5.15)	-0.935* (10.12)	-1.038* (7.69)	-0.861* (8.73)	-0.723* (2.23)	-0.385 (1.70)	-1.003* (3.71)
$\bar{R}^2$	0.288	0.379	0.559	0.588	0.773	0.115	0.124	0.308
θ	0.272* (5.78)	0.234* (2.05)	---	---	---	---	0.304* (2.60)	0.478* (3.77)
DW	---	---	2.251	2.665	2.243	2.203	---	---
Wald test	10.824*	1.292	0.495	0.080	1.978	0.735	7.438*	0.000

*Indicates significance at the 5 percent level. Absolute value of t-statistics in parentheses.

Table 3: Estimates of Variants of Equation 15 (1959.1-1993.12)				
Const.	0.065* (1.99)	0.049 (1.09)	0.004 (0.15)	-0.001 (0.03)
ΔNBR	-0.535* (6.21)	-0.405* (4.82)	-0.015 (0.17)	0.029 (0.33)
ΔAB	---	---	1.440* (10.61)	1.205* (9.36)
ΔSB	---	---	3.789* (4.88)	3.826* (4.42)
θ	---	0.336* (7.30)	---	0.249* (5.25)
$\bar{R}^2$	0.082	0.180	0.307	0.340
DW	1.356	---	1.601	---

*Indicates significance at the 5 percent level. Absolute value of t-statistics in parentheses.

Figure 1: Seasonal and Adjustment Borrowing and the Federal Funds - Discount Rate Spread

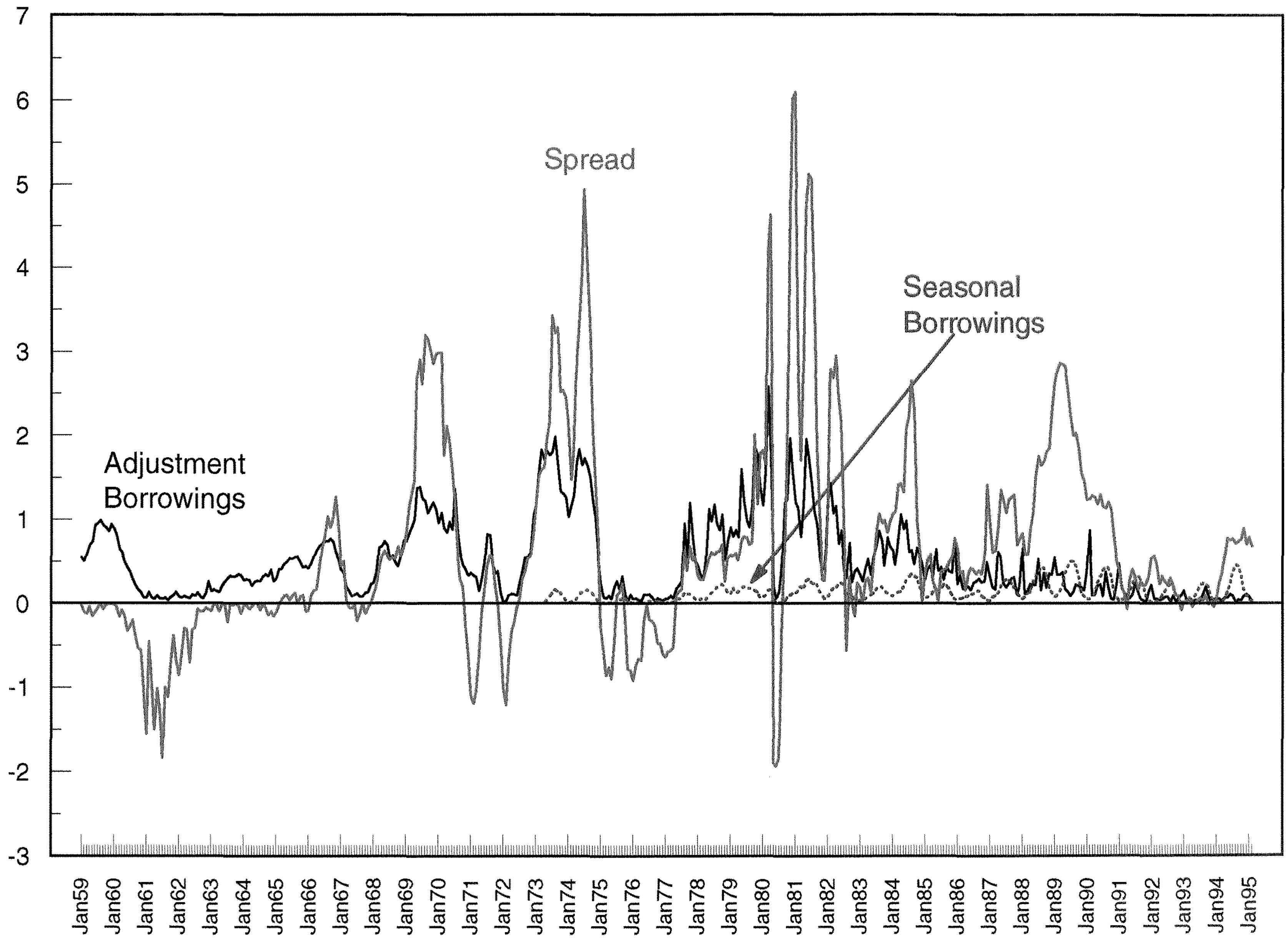


Figure 2: 60-Month Moving Correlations of ΔFF with ΔNBR and $-\Delta BR$

Jan/1964 - Dec/1993

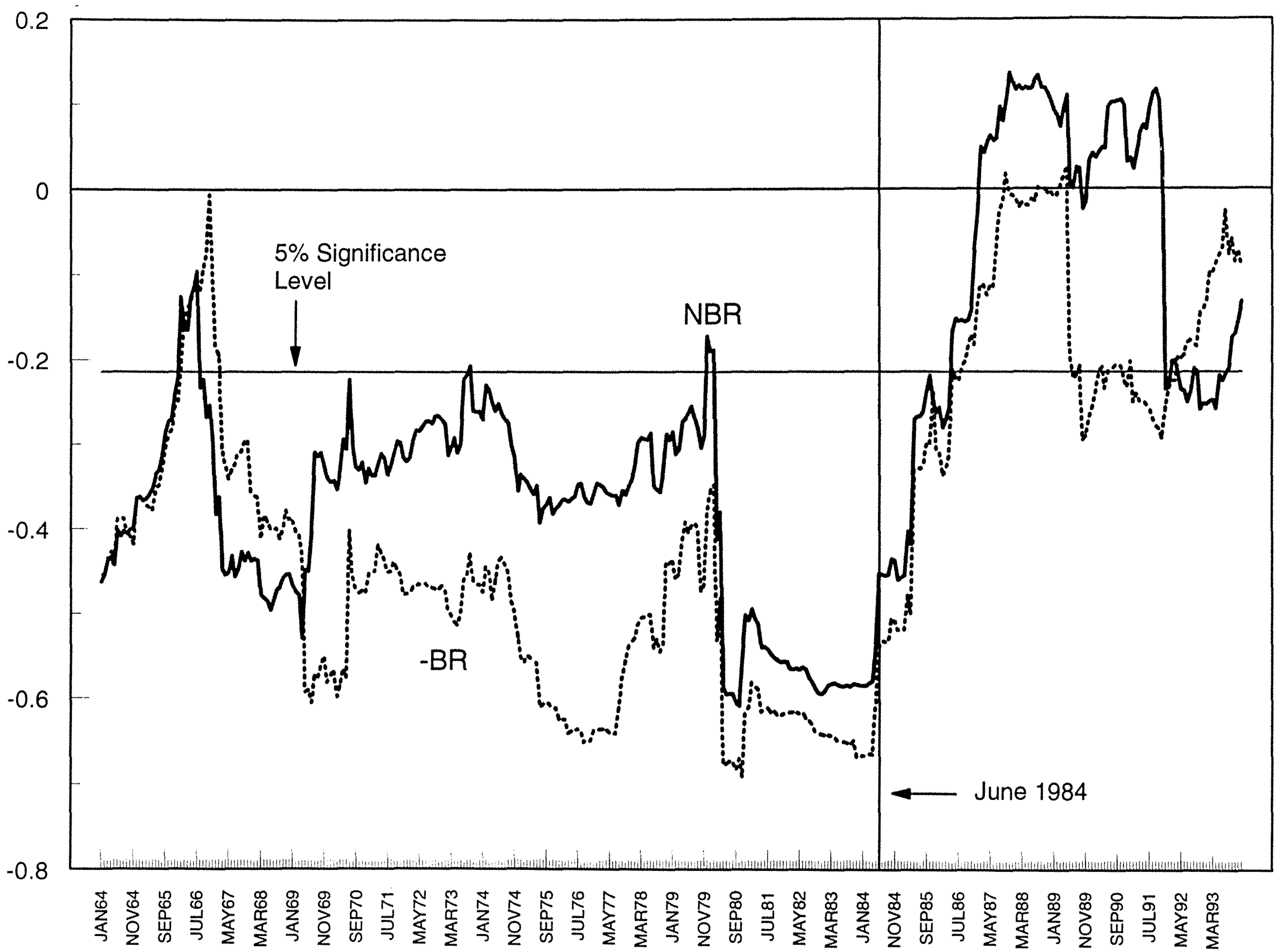


Figure 3: Impulse Response Functions - 59.1 to 93.12

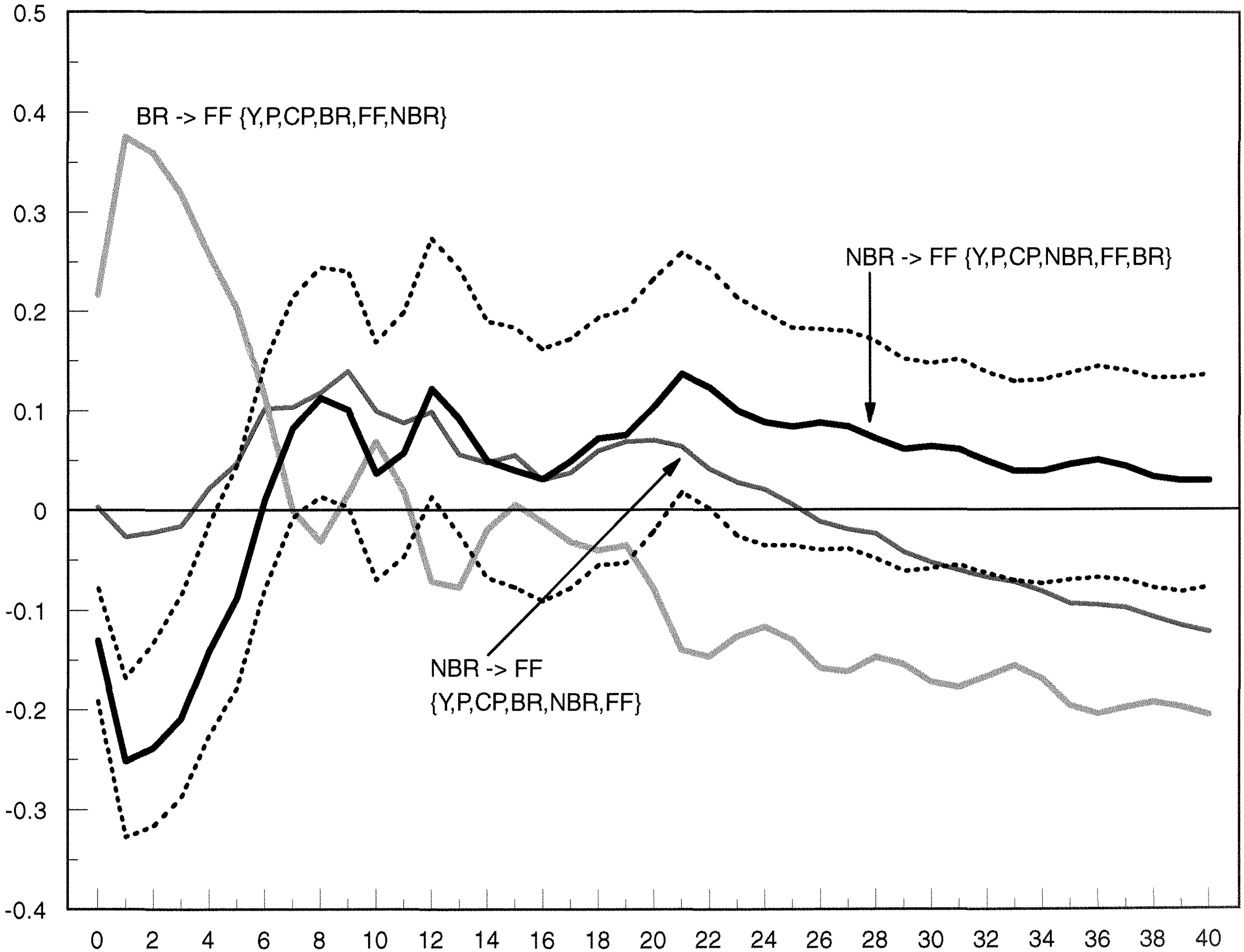


Figure 4: IRFs (Y, P, CP, NBR, FF, -BR)

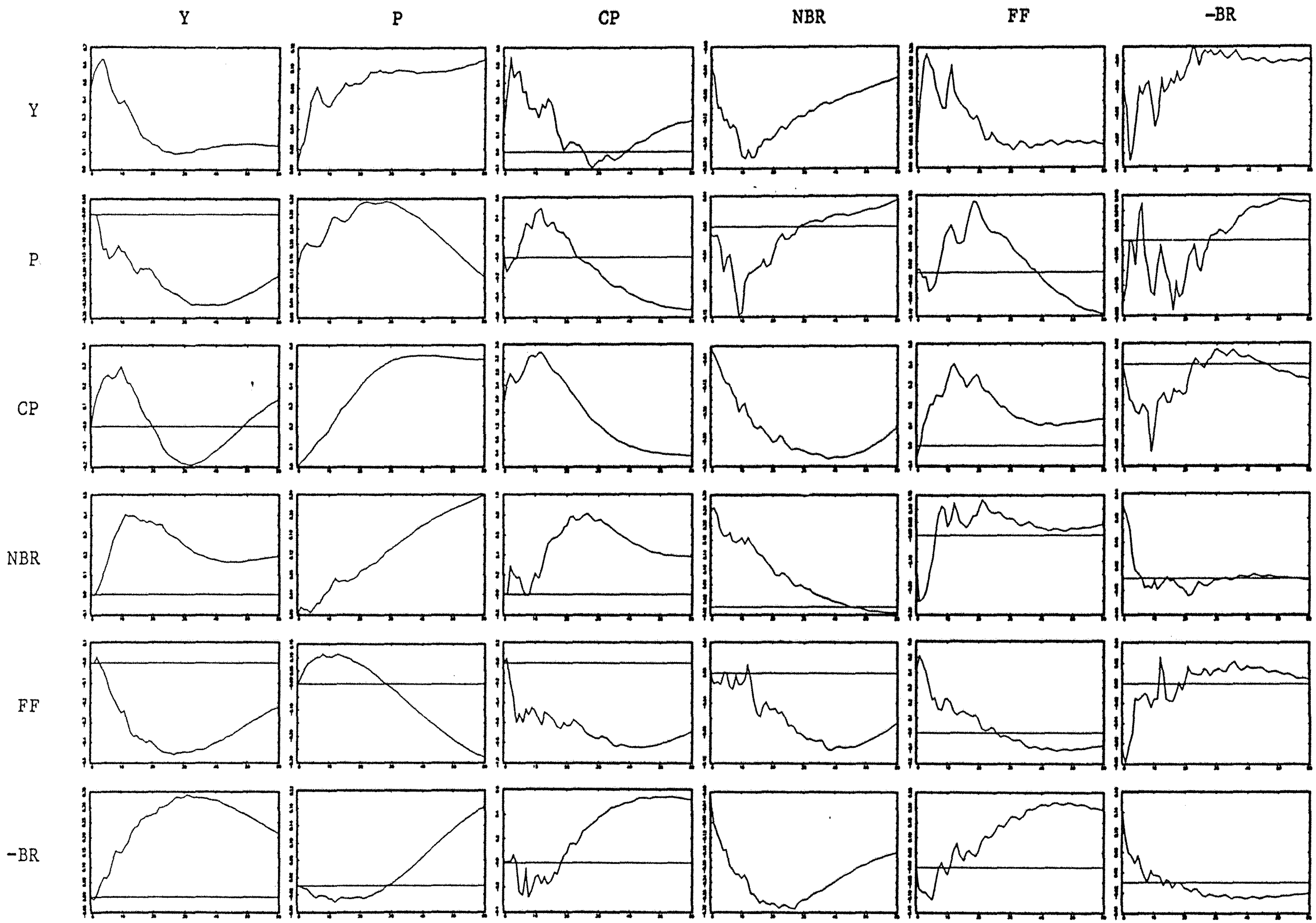


Figure 5: IRFs (Y, P, CP, -BR, FF, NBR)

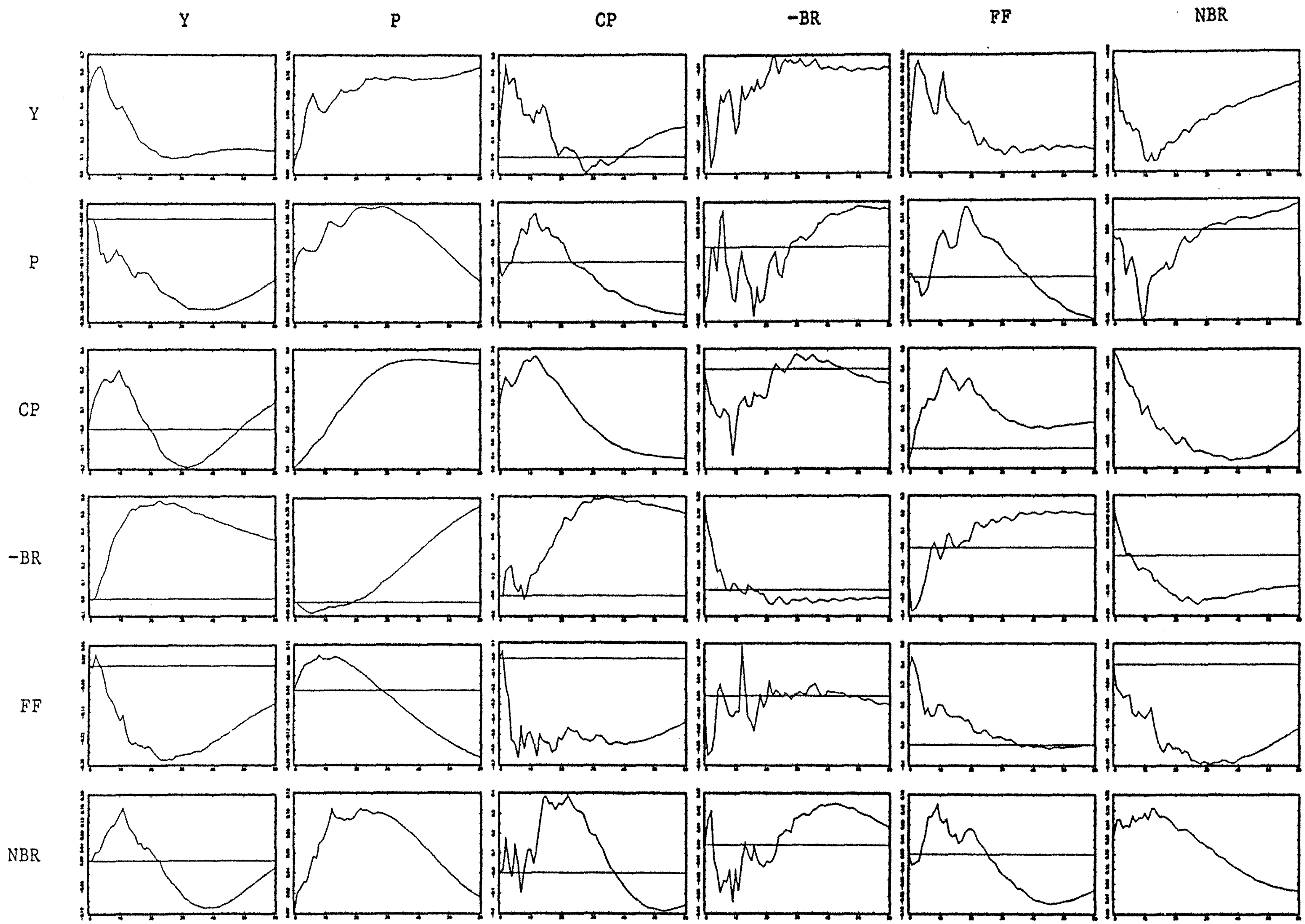


Figure 6: IRFs (Y, P, CP, -BR, NBR, FF)

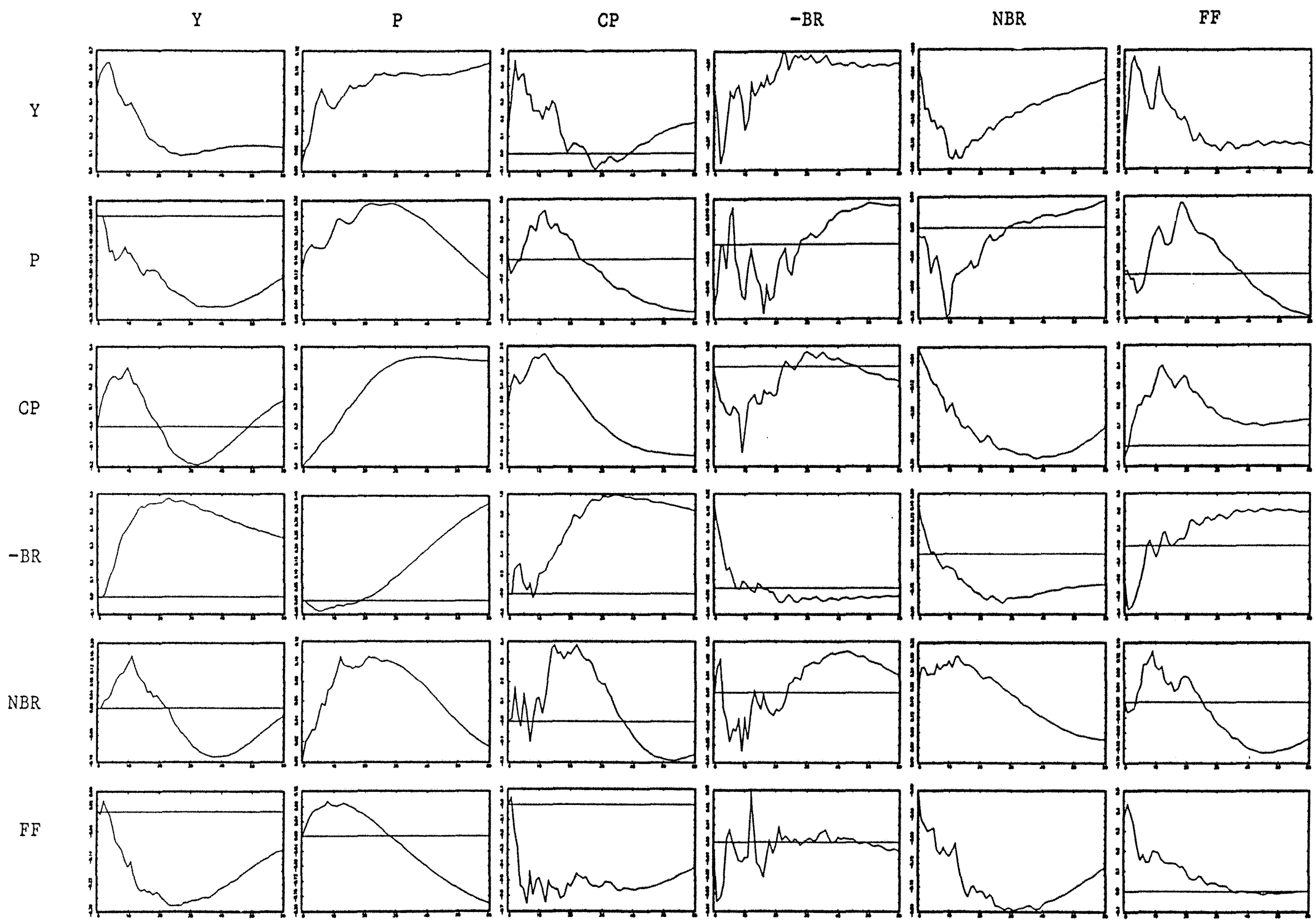


Figure 7: Impulse Response Functions - 59.1 to 65.2

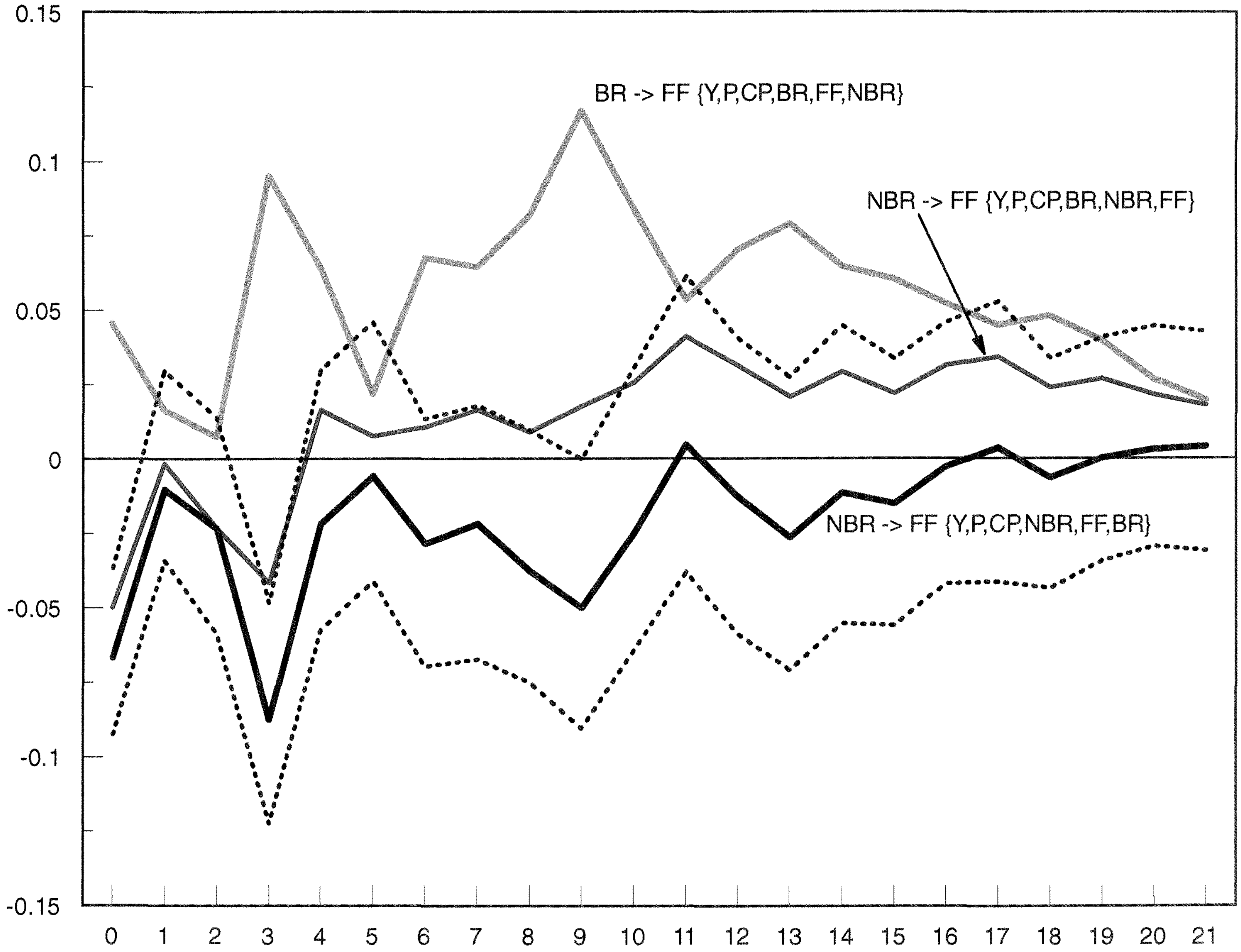


Figure 8: Impulse Response Functions - 59.1 to 73.4

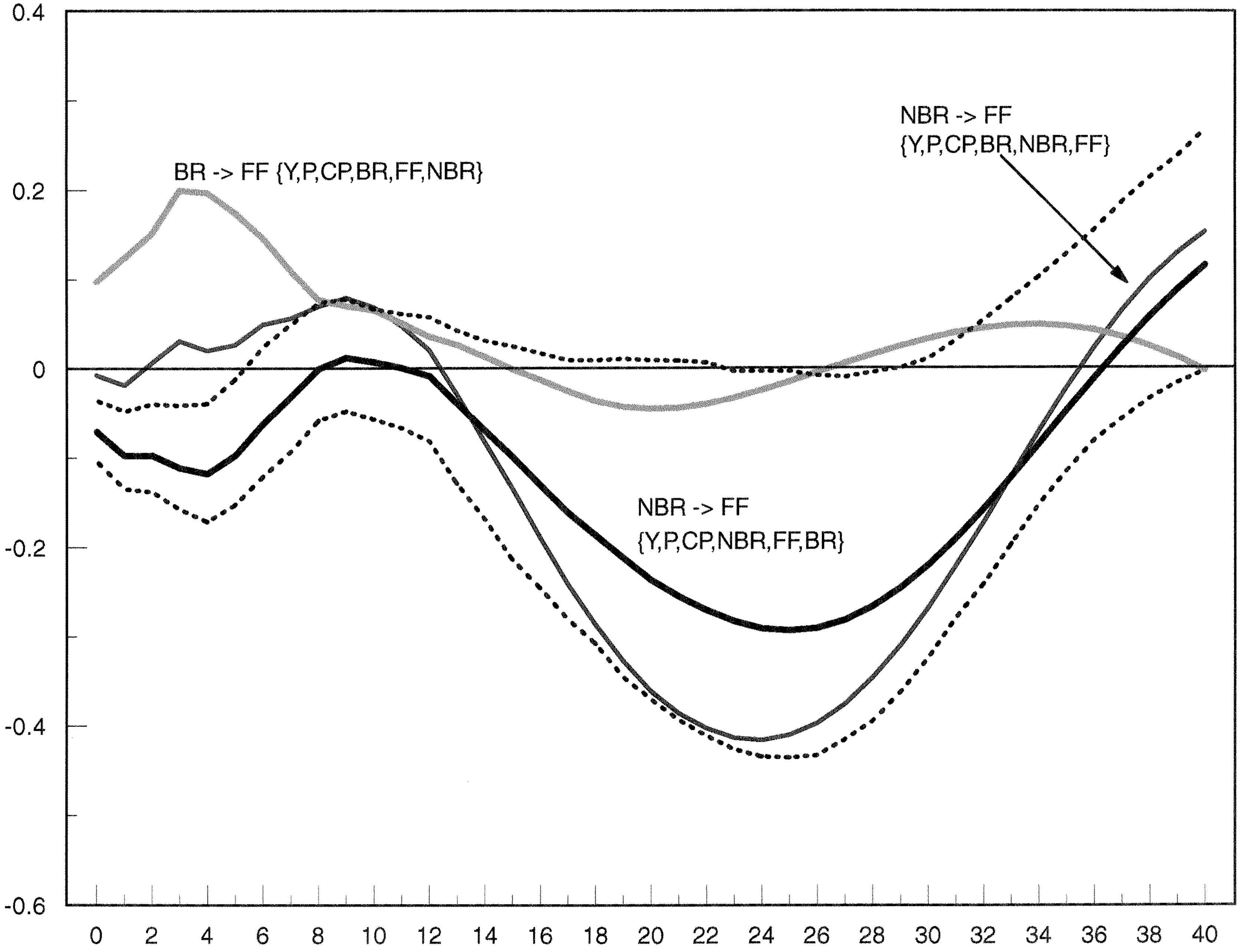


Figure 9: Impulse Response Functions - 73.5 to 84.6

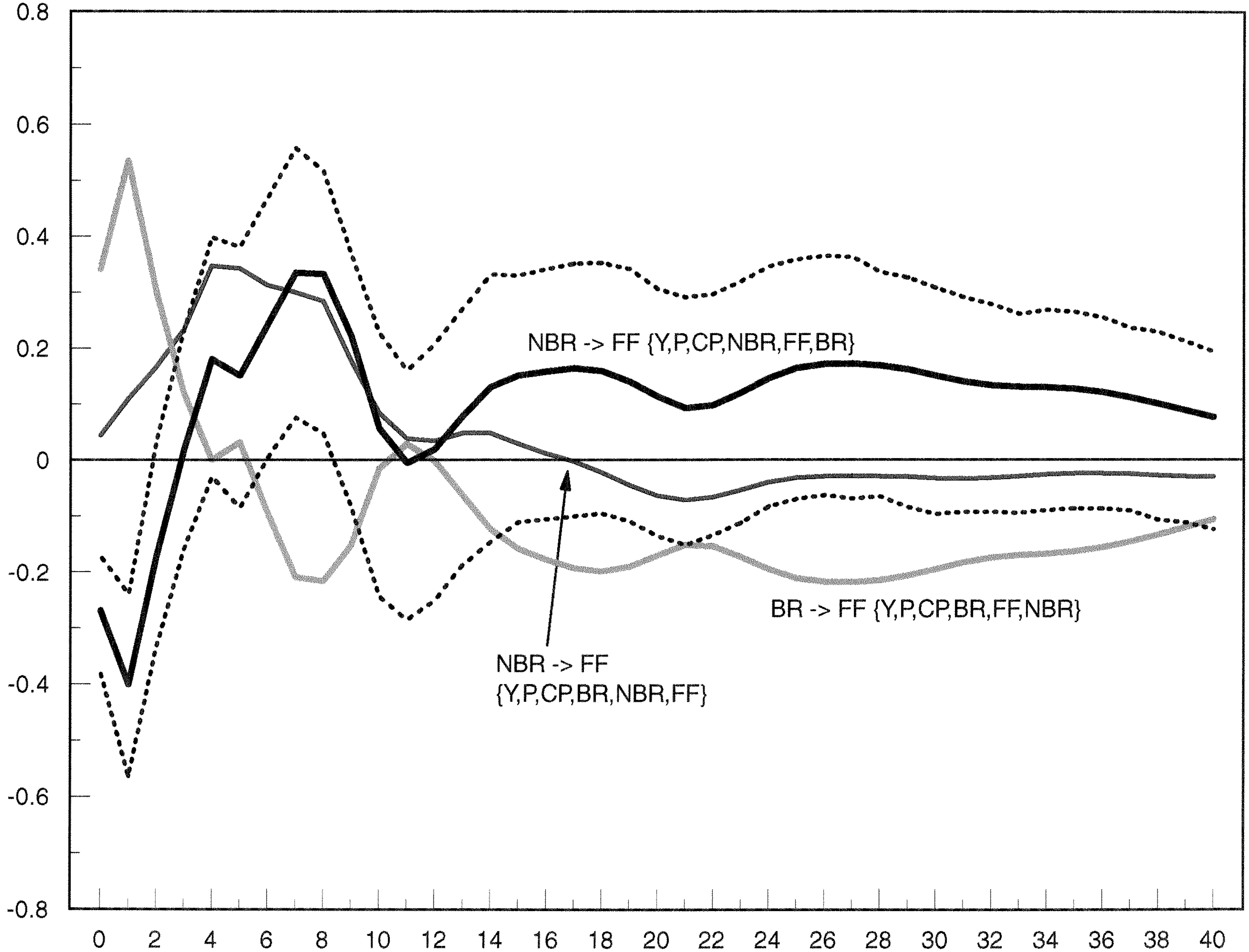


Figure 10: Impulse Response Functions - 77.9 to 84.6

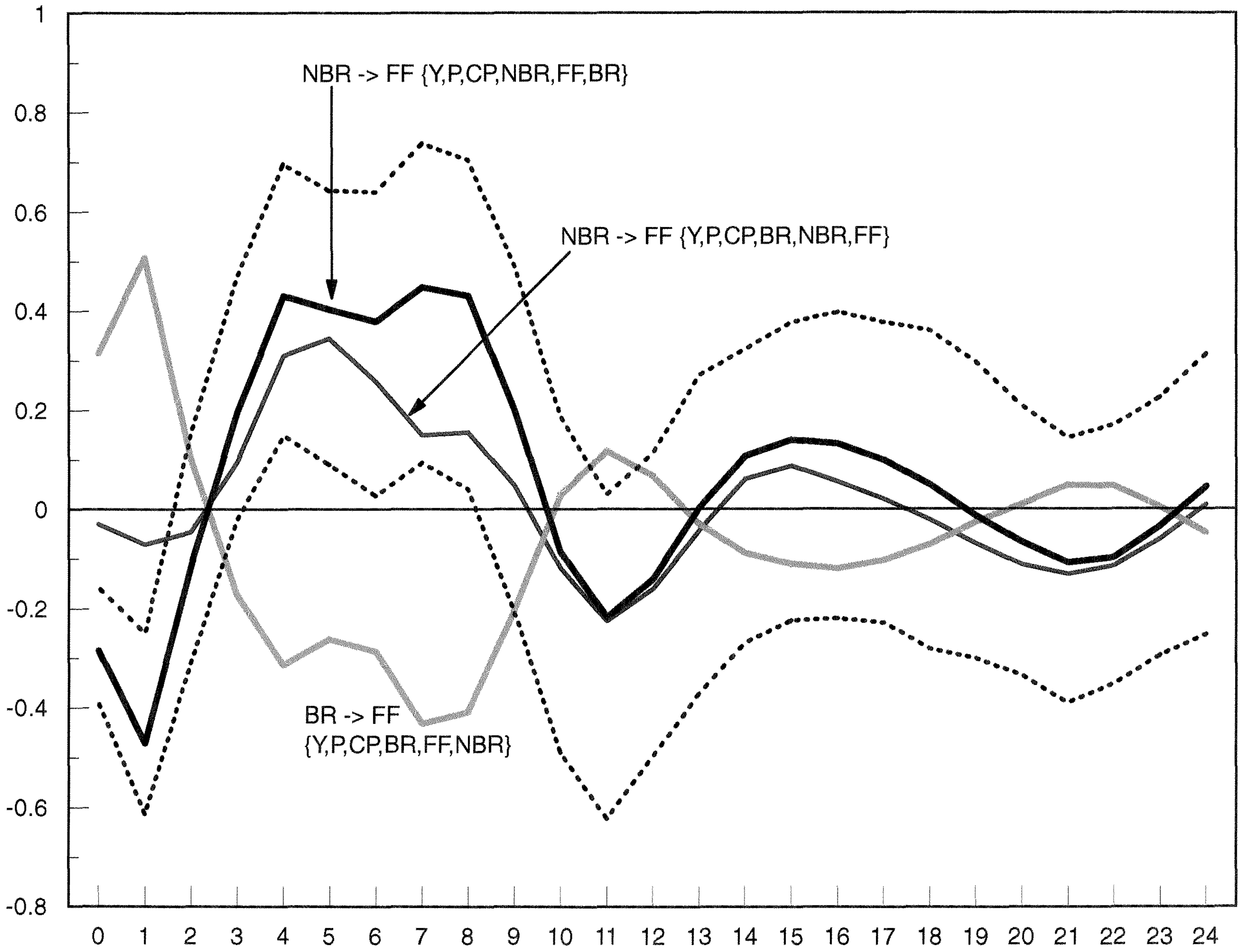


Figure 11: Impulse Response Functions - 84.7 to 93.12